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Single- and dual-source chest CT protocols: Levels of radiation dose in routine clinical practice

T. de Broucker [a], F. Pontana [a], T. Santangelo [a], J.-B. Faivre [a], N. Tacelli [a], V. Delannoy-Deken [b], A. Duhamel [b], J. Remy [a], M. Rémy-Jardin [a,*]

[a] *Department of Thoracic Imaging, hôpital Calmette, université Lille Nord de France, boulevard Jules-Leclercq, 59037 Lille cedex, France*
[b] *Department of Biostatistics, Université Lille Nord de France, 59000 Lille, France*

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Abstract
Purpose: To establish the radiation dose level for single- and dual-source thoracic CT scans in daily practice.
Materials and methods: The dose levels delivered during 634 consecutive examinations over a period of 2 months were recorded. The CT scans were performed using: (a) a standard protocol (single source, single energy [group 1]: $n = 266$; dual source, single energy [group 2]: $n = 276$; (b) with prospective ECG synchronisation [group 3]: $n = 13$; or (c) with dual energy [group 4]: $n = 79$. All the acquisitions included kilovoltage selection depending on the weight and automatic milliamperage modulation.
Results: The mean DLP of the standard protocols was 97.12 mGy cm (group 2; BMI = 23.1 kg/m^2) and 211.1 mGy cm (group 1; BMI = 27.3 kg/m^2), the choice of protocol depending on the diameter of the thorax relative to the diameter of the field of the second source, and therefore on the patient's morphotype. When imaging included examination of the proximal and middle coronary arteries (group 3), the mean DLP was 105.5 mGy cm. Morphological and functional imaging (group 4) was obtained with a mean DLP of 404.3 mGy cm.
Conclusion: Depending on the objective of the protocol, the mean DLP varied from 97.12 to 404.3 mGy cm.

Exposure to X-rays for medical, diagnostic or therapeutic purposes represents a large part of total exposure. In 2007, it was established that in France diagnostic procedures using ionising radiation led to a mean effective dose per inhabitant of 1.3 mSv, with estimated natural irradiation being 2.4 mSv/year [1]. The frequency distribution for these

* Corresponding author.
E-mail address: martine.remy@chru-lille.fr (M. Rémy-Jardin).

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procedures in France depending on the type of investigation, as established in 2007 by the French Institute for Public Health Surveillance (Institut de Veille Sanitaire), is 63% conventional radiology (excluding dental procedures), 24.7% dental radiology, 10.1% computed tomography (CT), 1.6% nuclear medicine and 0.6% interventional radiology [1]. CT plays a prominent role in total diagnostic exposure to X-rays, especially as it is now replacing a large number of conventional examinations: in 2007 in France, 58% of the total collective effective dose was from CT scans [1]. The subject of risks is a growing preoccupation, particularly the carcinogenic risks of ionising radiation. For a number of years radiologists and nuclear medicine doctors have been very concerned with reducing these risks, a matter which has become a legal obligation since the European directive 97/43 was adopted [2]. Apart from the essentials of justifying the examinations, radiologists have agreed to optimise the examinations performed. In thoracic CT, several means of optimisation have been considered such as the use of bismuth impregnated shielding [3], adjustment of settings depending on the patient's morphotype [4—10], collimation adjustment [11], and the use of automatic milliamperage modulation [12—15]. The aim of our work was to establish the dose levels of irradiation in thoracic CT, recorded in daily CT practice in a specialised thoracic imaging department, and to compare them with the current French recommendations.

Materials and methods

Study population

In order to study the dose levels delivered in the daily CT scanning of adults in a thoracic imaging department of a university hospital, the population of this study was prospectively included over a period of two months (July 2010—August 2010). It included any adult outpatient or inpatient referred for a thoracic CT examination, with or without injection of contrast agent, but excluded patients referred for a puncture procedure or percutaneous drainage. Patients had been referred from outpatient day treatment units and conventional inpatient departments, other than intensive care.

Examination protocols

The examinations were performed using a single machine (Somatom Definition Flash, Siemens, Forchheim, Germany). There were four management protocols:

(a) single source, single energy, without ECG gating (protocol 1);
(b) dual source, single energy, without ECG gating (protocol 2);
(c) dual source, single energy with prospective ECG gating (protocol 3);
(d) dual source, dual energy (protocol 4).

For our team, protocols 1 and 2 are routine standard protocols for a thoracic CT examination. Protocol 3 is indicated when we wish to include morphological information on the coronary arteries in the standard thoracic CT examination, and protocol 4 is for any CT angiographic examination requiring standard morphological information to be linked to study of the pulmonary perfusion. As regards the standard protocol, protocol 2 was preferred because of greater temporal resolution (75 ms vs. 140 ms) and higher pitch (pitch 3.0 vs. pitch 1.5) reducing the acquisition time to about one 1 second for the entire length of the thorax; it did however depend on the circumference of the patient's chest since the field of tube B is narrower than that of tube A, only covering 33 cm. Consequently, protocol 1 became the standard protocol by default for any patient with a thoracic diameter greater than 33 cm.

With the exception of acquisitions with ECG synchronisation (protocol 3) based on fixed kilovoltage and milliamperage, the choice of irradiation parameters of the other protocols depended on the weight of the patient in conjunction with the criteria summarised in Table 1 (protocols 1 and 2) and Table 2 (protocol 4). The main characteristics of the acquisition parameters of the four protocols are summarised in Table 3. In all cases, acquisition was always in the craniocaudal direction, in forced inspiration with the arms raised above the head. Reconstructions (pulmonary and mediastinal images) were systematically in transverse adjacent, 1 mm slices, with a high spatial frequency algorithm (B50; pulmonary images) and a density resolution filter (B20; mediastinal images).

Study parameters

The following data were collected for each patient:

Table 1 Selection of kilovoltage and milliamperage according to the weight of the patient for single- or dual-source, simple energy computed tomography (protocols 1 & 2).

Patient weight (kg)	Kilovoltage (kV)	Charge (reference mAs)
< 50	80	120
50—80	100	90
81—100	120	90
≥ 100	140	90—140

kg: kilogram; kV: kilovolt; mAs: milliampere-second.

Table 2 Selection of the kilovoltage and milliamperage according to the weight of the patient in dual energy computed tomography (protocol 4).

Patient ≤ 110 kg	Patient > 110 kg
Tube A: 80 kV; 300 mAs	Tube A: 100 kV; 250 mAs
Tube B: 140 Sn kV; 100 mAs	Tube B: 140 Sn kV; 100 mAs
4D modulation of the milliamperage: inactivated	4D modulation of the milliamperage: inactivated
Collimation: 32 × 0.6 mm	Collimation: 32 × 0.6 mm
Pitch: 0.5	Pitch: 0.6